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PROJECT APOLLO

PERFORMANCE OF THE LUNAR MODULE ASCENT PROPULSION SYSTEM IN A BLOWDOWN MODE

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SUMMARY AND INTRODUCTION

A mode of failure which has been hypothesized for the lunar module ascent engine is the loss of helium pressure to the propellant tanks. Following such a failure, the ascent engine could operate in a "blowdown" mode under certain conditions. This mode of operation is one in which the ullage volume of helium in the propellant tanks is allowed to expand to drive the engine. This mode of operation has been simulated through the use of a mathematical model of the engine, the Rocket Engine Model, developed under MSC/TRW Task A-40 and using engine model parameters from reference 1.

This report presents the results of that simulation. The performance available from the engine in the blowdown mode is a function of the ullage volume and pressure at the time of the failure, and the results given here are for various significant combinations of initial conditions which correspond to particular failure modes and limiting cases.

DISCUSSION AND RESULTS

Studies at MSC (ref. 2) and North American Aviation for mission AS-202 indicated that the second service propulsion system (SPS) burn for that mission could have been performed in a blowdown mode. The results of these studies inspired interest in the performance potential of the lunar module ascent engine in a blowdown mode.

The ullage volume of helium in the propellant tanks at the beginning of the second SPS burn for the AS-202 mission was quite large relative to the volume of propellant expended during the second burn. Consequently, the pressure of the expanded helium at the end of the burn was still relatively high. This study for the ascent propulsion system is mission independent, and several limiting cases of initial conditions were considered.

Figure 1 is a schematic of the ascent propellant system, and figure 2 shows the engine injector and valves. The propellant valve actuators are operated by fuel pressure and begin to close when the fuel pressure drops to 70 psi and should be completely closed at 30 psi.

Figure 3 simulates a condition in which the failure occurs after full pressurization of the tanks (to the nominal ullage pressure of 182 psi) and with the tanks initially full of propellants, i.e., with only the nominal initial ullage volumes of helium. Figure 3(a) corresponds to an isothermal (constant temperature) expansion of the helium, and figure 3(b) corresponds to the adiabatic (no heat addition) expansion. It is recommended that the adiabatic expansion curves be used since any heat transferred to the helium during the burn would be counteracted by the work required to pump the propellants through the engine. The dashed portions of the curves indicate the region where the 70-psi fuel pressure has been reached; engine performance predictions in this region will be questionable.

Figure 4 corresponds to a failure with the tanks half full of propellants and with an initial nominal ullage pressure. With the isothermal expansion, the engine should operate to propellant depletion without falling below the 70-psi limit. However, it is again recommended that the adiabatic expansion process be considered more realistic.

The failure considered in figure 5 is one with the tanks initially half full and an initial ullage pressure of 100 psi (the minimum specified pressure at lift-off). Again assuming an adiabatic expansion, the engine would operate for about 103 seconds.

CONCLUSIONS

The performance available from the lunar module ascent propulsion system in a blowdown mode is strongly a function of the initial conditions existing at the time of the failure of the pressurizing system. The curves in this report may be considered as limiting cases for the performance of the ascent engine in the blowdown mode, from which the performance for various initial conditions may be estimated for mission planning purposes.

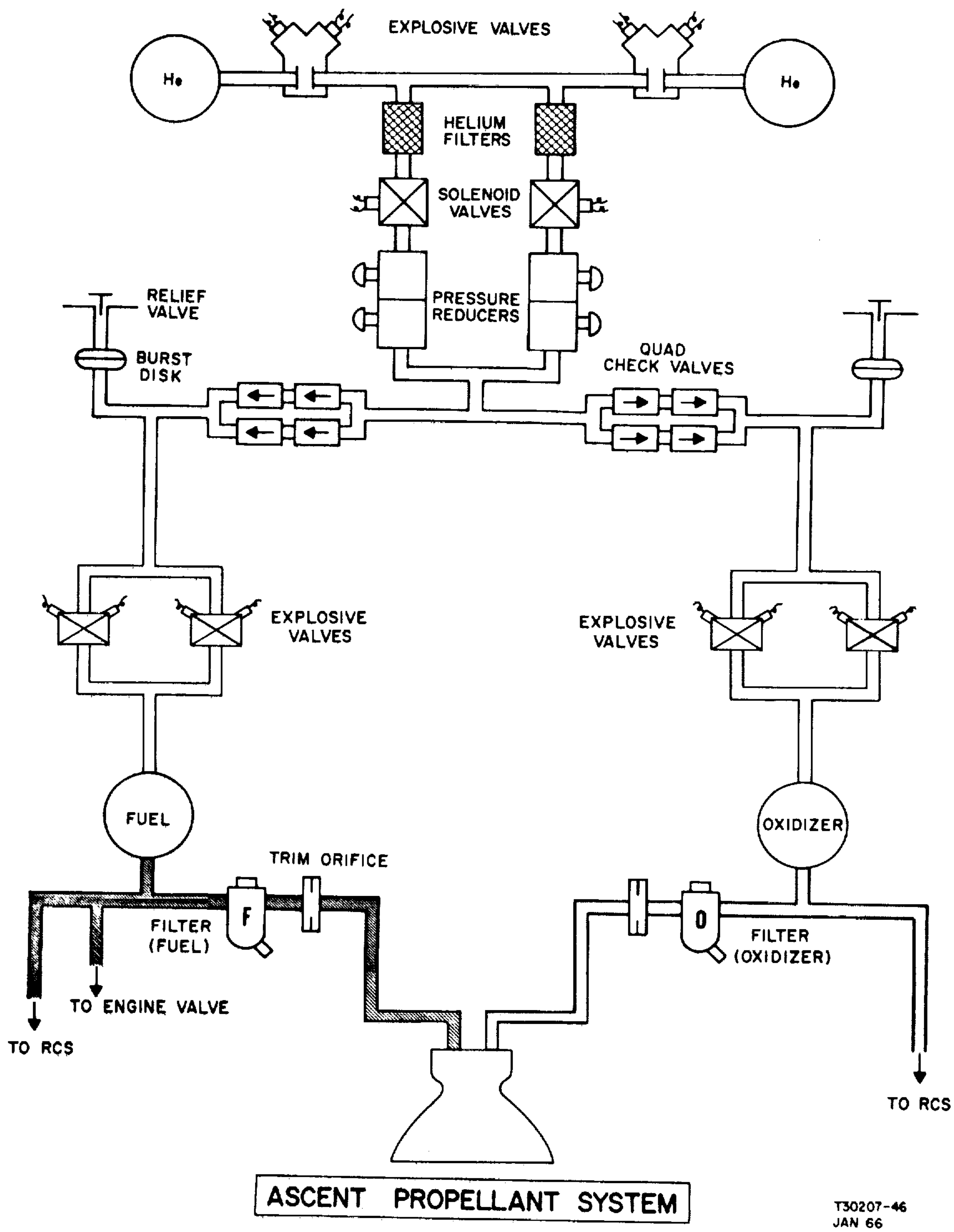


Figure 1.- Ascent propellant system (ref. 3, p. 46).

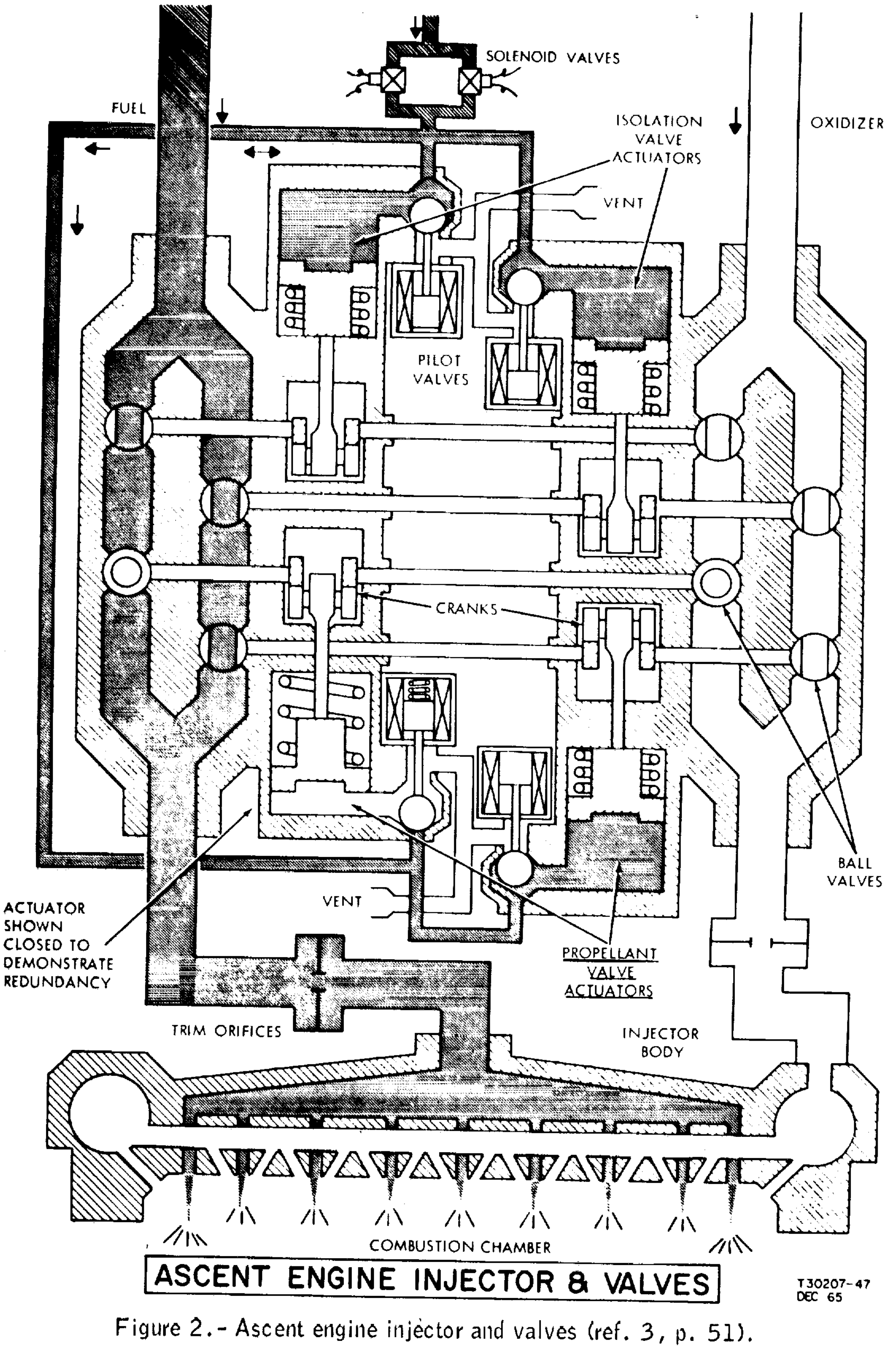
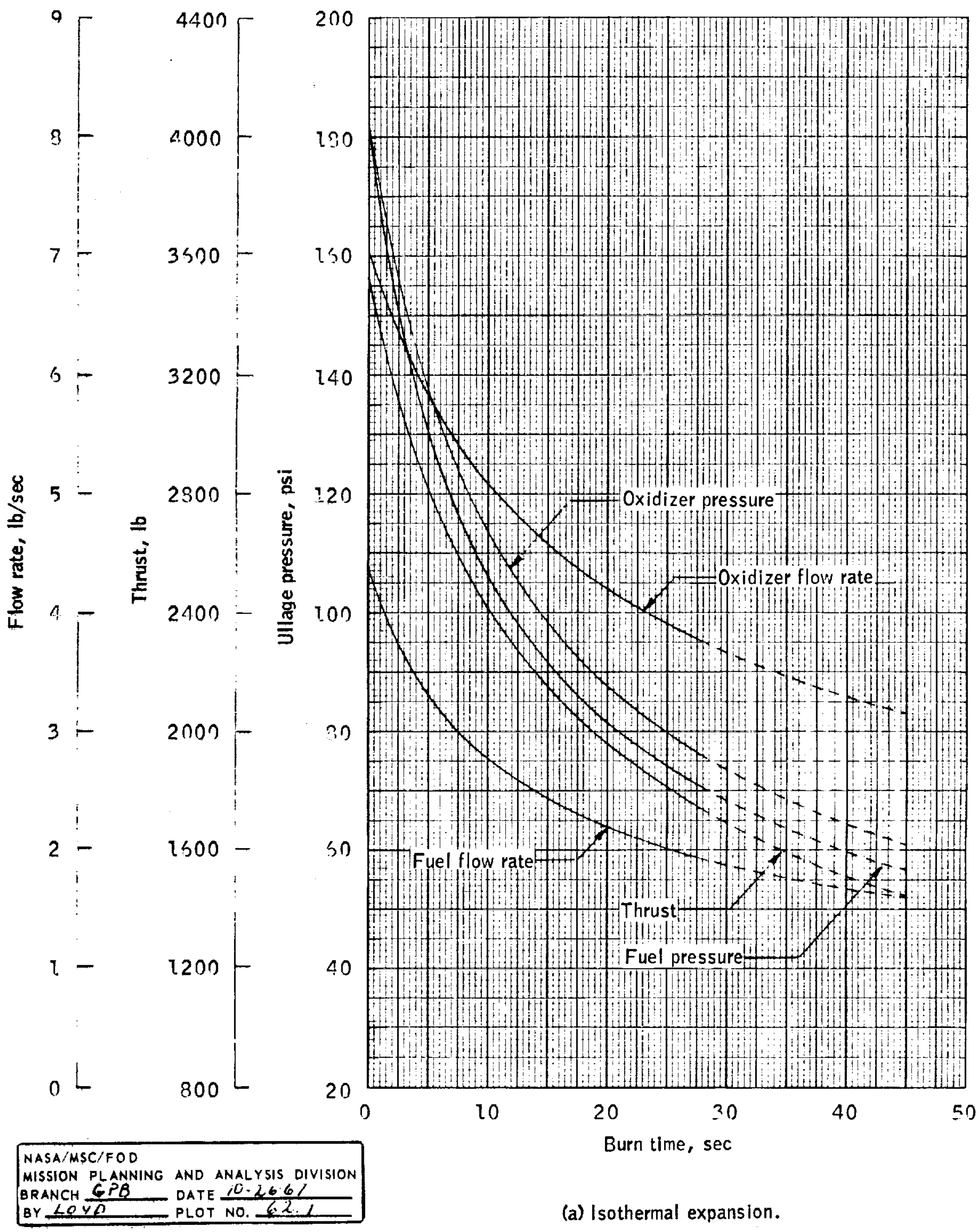
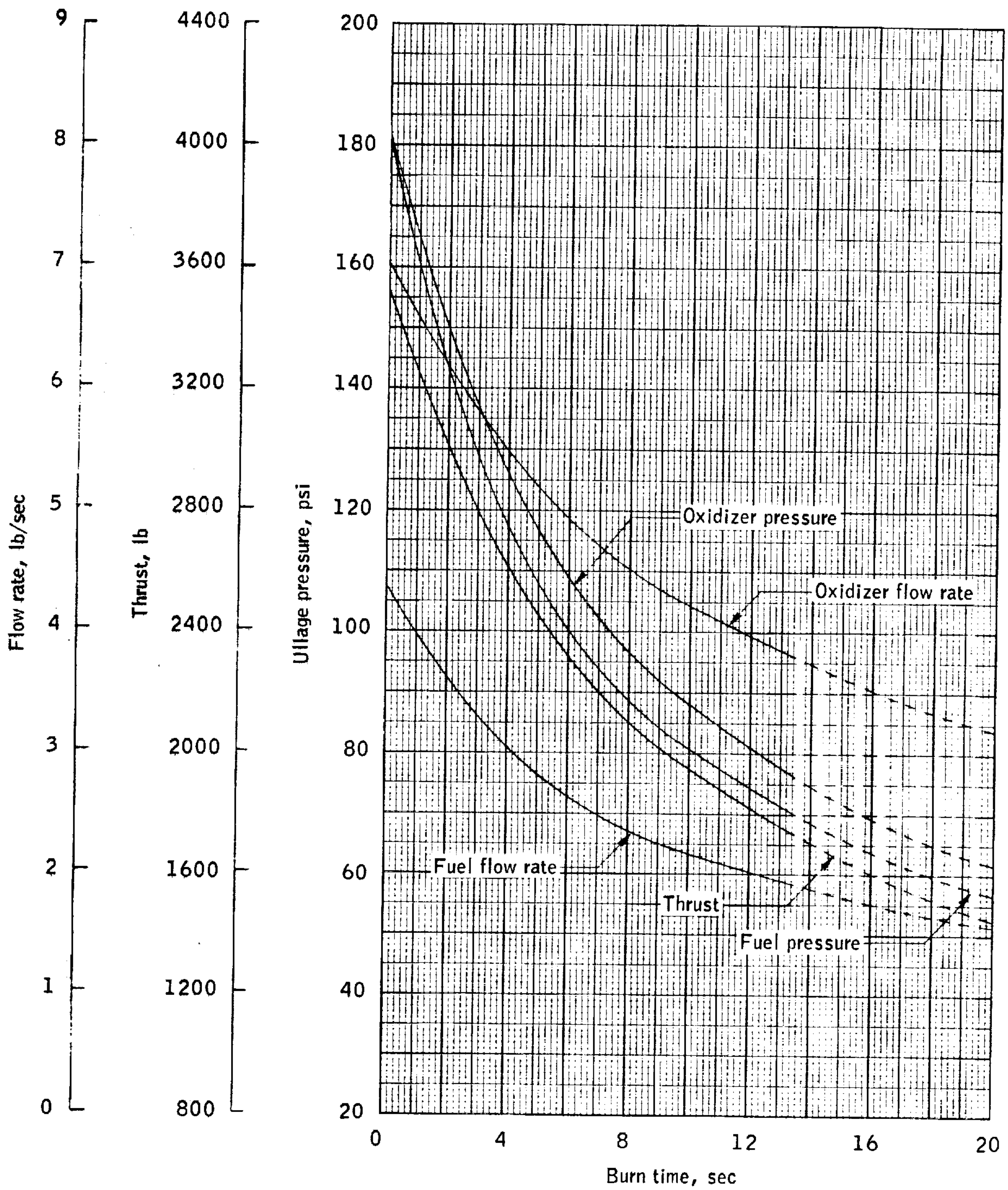


Figure 2.- Ascent engine injector and valves (ref. 3, p. 51).



(a) Isothermal expansion.

Figure 3.- APS Engine in blowdown mode; tanks initially full.



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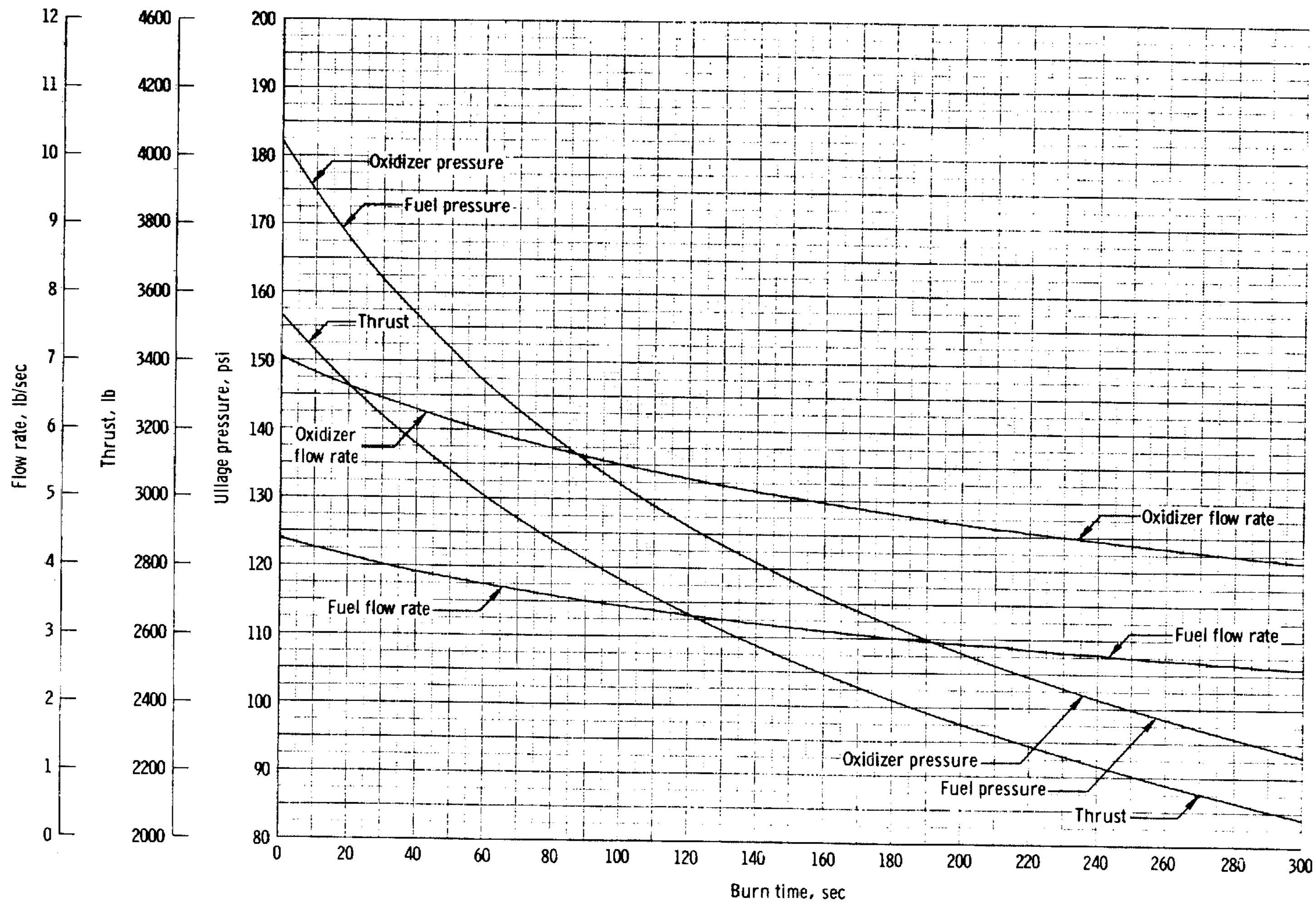
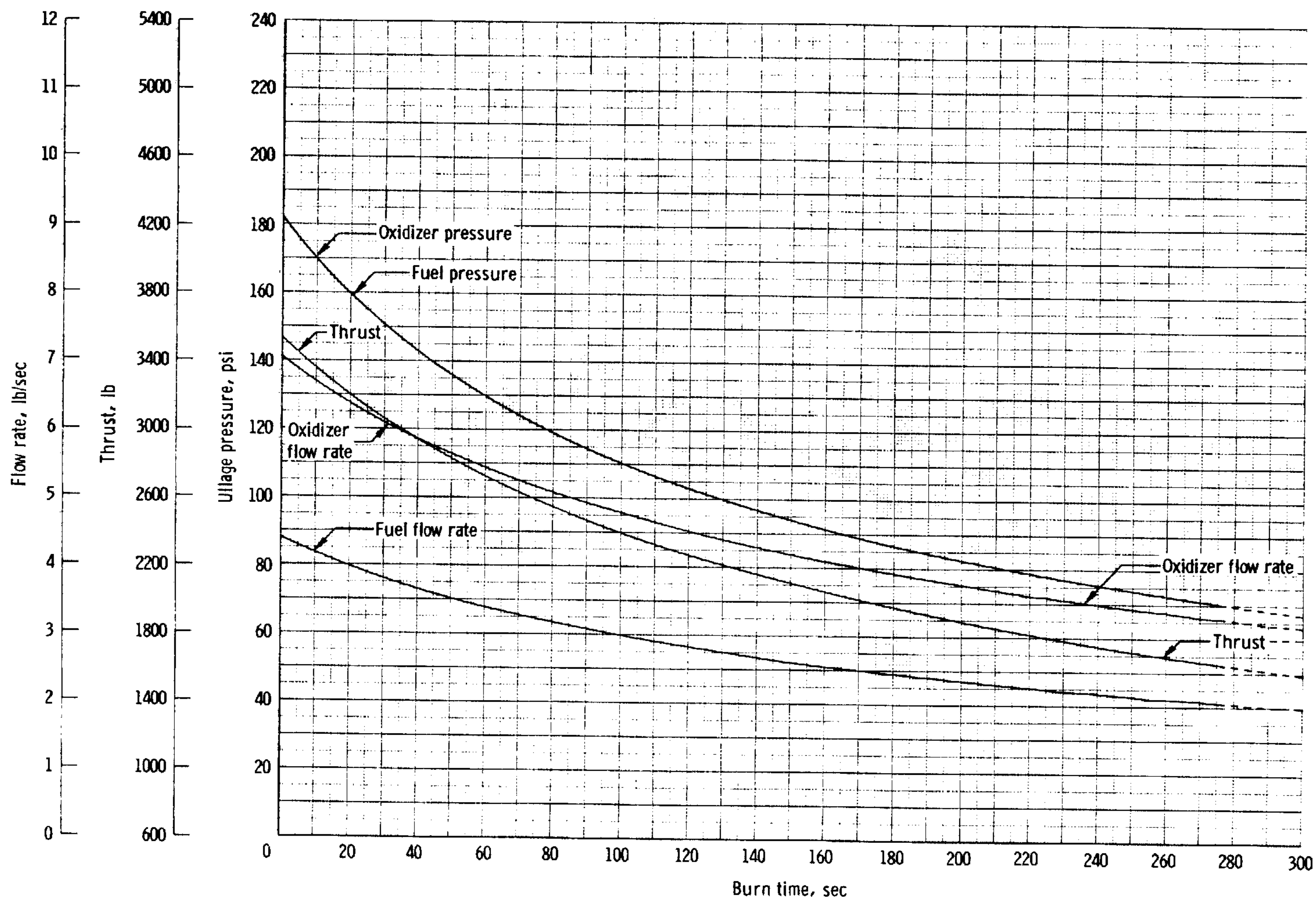
(b) Adiabatic expansion.

Figure 3.- Concluded.



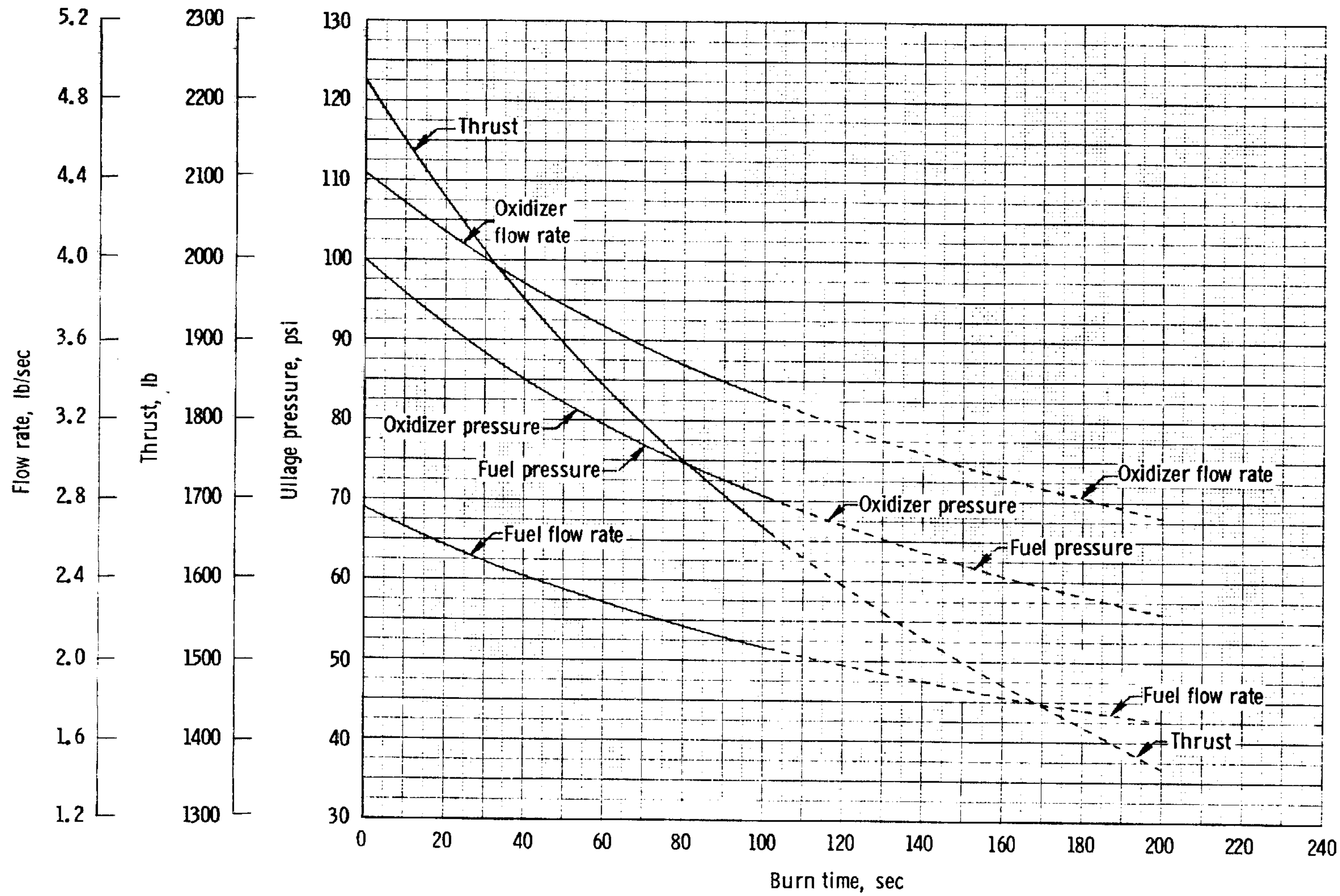
(a) Isothermal expansion.

Figure 4.- APS engine in blowdown mode; tanks initially half full.



(b) Adiabatic expansion.

Figure 4.- Concluded.



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(b) Adiabatic expansion.

Figure 5.- Concluded.

REFERENCES

1. Palmer, A. R.: Apollo Spacecraft Propulsion Models. TRW Note No. 67-FMT-498, March 15, 1967.

2. Loyd, A. J.; and Nelson, D. A.: Performance of the Service Propulsion System in a Blowdown Mode During the Second Burn of the AS-202 Mission. MSC Memorandum No. 66-FM7-120, August 17, 1966.

3. LM Propulsion and RCS Study Guide. GAEC Training Document, Course No. 30215, March 7, 1966.